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THE NEW WORLD-PICTURE OF MODERN PHYSICS[1]

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THE British Association assembles for the third time in Aberdeen—under the happiest of auspices. It is good that we are meeting in Scotland, for the association has a tradition that its Scottish meetings are wholly successful. It is good that we are meeting in the sympathetic atmosphere of a university city, surrounded not only by beautiful and venerable buildings, but also by buildings in which scientific knowledge is being industriously and successfully accumulated. And it is especially good that Aberdeen is rich not only in scientific buildings but also in scientific associations. Most of us can think of some master-mind in his own subject who worked here. My own thoughts, I need hardly say, turn to James Clerk Maxwell.

[1] Presidential address, delivered before the meeting of the British Association for the Advancement of Science, Aberdeen, on September 5, 1934.

Whatever our subject, there is one man who will be in our thoughts in a very special sense to-night—Sir William Hardy, whom we had hoped to see in the presidential chair this year. It was not to be, and his early death, while still in the fulness of his powers, casts a shadow in the minds of all of us. We all know of his distinguished work in pure science, and his equally valuable achievements in applied science. I will not try to pay tribute to these, since it has been arranged that others, better qualified than myself, shall do so in a special memorial lecture. Perhaps, however, I may be permitted to bear testimony to the personal qualities of one whom I was proud to call a friend for a large part of my life, and a colleague for many years. Inside the council room, his proposals were always acute, often highly original and invariably worthy of careful consideration; outside, his big

personality and wide range of interests made him the most charming and versatile of friends.

And now I must turn to the subject on which I have specially undertaken to speak—the new world-picture presented to us by modern physics. It is a full half-century since this chair was last occupied by a theoretical physicist in the person of the late Lord Rayleigh. In that interval the main edifice of science has grown almost beyond recognition, increasing in extent, dignity and beauty, as whole armies of laborers have patiently added wing after wing, story upon story and pinnacle to pinnacle. Yet the theoretical physicist must admit that his own department looks like nothing so much as a building which has been brought down in ruins by a succession of earthquake shocks.

The earthquake shocks were, of course, new facts of observation, and the building fell because it was not built on the solid rock of ascertained fact, but on the ever-shifting sands of conjecture and speculation. Indeed it was little more than a museum of models, which had accumulated because the old-fashioned physicist had a passion for trying to liken the ingredients of nature to familiar objects such as billiard-balls, jellies and spinning tops. While he believed and proclaimed that nature had existed and gone her way for countless eons before man came to spy on her, he assumed that the latest newcomer on the scene, the mind which could never get outside itself and its own sensations, would find things within its limited experience to explain what had existed from all eternity. It was expecting too much of nature, as the ruin of our building has shown. She is not so accommodating as this to the limitations of the human mind; her truths can only be made comprehensible in the form of parables.

Yet no parable can remain true throughout its whole range to the facts it is trying to explain. Somewhere or other it must be too wide or too narrow, so that "the truth, the whole truth, and nothing but the truth" is not to be conveyed by parables. The fundamental mistake of the old-fashioned physicist was that he failed to distinguish between the half-truths of parables and the literal truth.

Perhaps his mistake was pardonable, perhaps it was even natural. Modern psychologists make great use of what they describe as "word-association." They shoot a word at you, and ask you to reply immediately with the first idea it evokes in your uncontrolled mind. If the psychologist says "wave," the boy scout will probably say "flag," while the sailor may say "sea," the musician "sound," the engineer "compression" and the mathematician "sine" or "cosine." Now the crux of the situation is that the number of people who will give this last response is very small. Our remote ancestors did not survive in the struggle for existence by pondering over sines and cosines, but by devising ways of killing other animals without being killed themselves. As a consequence, the brains we have inherited from them take more kindly to the concrete facts of everyday life than to abstract concepts; to particulars rather than to universals. Every child, when first it begins to learn algebra, asks in despair "But what are x, y and z?" and is satisfied when, and only when, it has been told that they are numbers of apples or pears or bananas or something such. In the same way, the old-fashioned physicist could not rest content with x, y and z, but was always trying to express them in terms of apples or pears or bananas. Yet a simple argument will show that he can never get beyond x, y and z.

Physical science obtains its knowledge of the external world by a series of exact measurements or, more precisely, by comparisons of measurements. Typical of its knowledge is the statement that the line Hα in the hydrogen spectrum has a wave-length of so many centimeters. This is meaningless until we know what a centimeter is. The moment we are told that it is a certain fraction of the earth's radius, or of the length of a bar of platinum, or a certain multiple of the wave-length of a line in the cadmium spectrum, our knowledge becomes real, but at that same moment it also becomes purely numerical. Our minds can only be acquainted with things inside themselves—never with things outside. Thus we can never know the essential nature of anything, such as a centimeter or a wave-length, which exists in that mysterious world outside ourselves to which our minds can never penetrate; but we can know the numerical ratio of two quantities of similar nature, no matter how incomprehensible they may both be individually.

For this reason, our knowledge of the external world must always consist of numbers, and our picture of the universe—the synthesis of our knowledge—must necessarily be mathematical in form. All the concrete details of the picture, the apples and pears and bananas, the ether and atoms and electrons, are mere clothing that we ourselves drape over our mathematical symbols—they do not belong to nature, but to the parables by which we try to make nature comprehensible. It was, I think, Kronecker who said that in arithmetic God made the integers and man made the rest; in the same spirit, we may add that in physics God made the mathematics and man made the rest.

The modern physicist does not use this language, but he accepts its implications, and divides the concepts of physics into observables and unobservables. In brief, the observables embody facts of observation, and so are purely numerical or mathematical in their

content; the unobservables are the pictorial details of the parables.

The physicist wants to make his new edifice earthquake-proof—immune to the shock of new observations—and so builds only on the solid rock, and with the solid bricks, of ascertained fact. Thus he builds only with observables, and his whole edifice is one of mathematics and mathematical formulae—all else is man-made decoration.

For instance, when the undulatory theory had made it clear that light was of the nature of waves, the scientists of the day elaborated this by saying that light consisted of waves in a rigid, homogeneous ether which filled all space. The whole content of ascertained fact in this description is the one word "wave" in its strictly mathematical sense; all the rest is pictorial detail, introduced to help out the inherited limitations of our minds.

Then scientists took the pictorial details of the parable literally, and so fell into error. For instance, light-waves travel in space and time jointly, but by filling space and space alone with ether, the parable seemed to make a clear-cut distinction between space and time. It even suggested that they could be separated out in practise—by performing a Michelson-Morley experiment. Yet, as we all know, the experiment when performed only showed that such a separation is impossible; the space and time of the parable are found not to be true to the facts—they are revealed as mere stage-scenery. Neither is found to exist in its own right, but only as a way of cutting up something more comprehensive—the space-time continuum.

Thus we find that space and time can not be classified as realities of nature, and the generalized theory of relativity shows that the same is true of their product, the space-time continuum. This can be crumpled and twisted and warped as much as we please without becoming one whit less true to nature —which, of course, can only mean that it is not itself part of nature.

In this way space and time, and also their space-time product, fall into their places as mere mental frameworks of our own construction. They are of course very important frameworks, being nothing less than the frameworks along which our minds receive their whole knowledge of the outer world. This knowledge comes to our minds in the form of messages passed on from our senses; these in turn have received them as impacts or transfers of electromagnetic momentum or energy. Now Clerk Maxwell showed that electromagnetic activity of all kinds could be depicted perfectly as traveling in space and time—this was the essential content of his electromagnetic theory of light. Thus space and time are of preponderating importance to our minds as the media through which the messages from the outer world enter the "gateways of knowledge," our senses, and in terms of which they are classified. Just as the messages which enter a telephone exchange are classified by the wires along which they arrive, so the messages which strike our senses are classified by their arrival along the space-time framework.

Physical science, assuming that each message must have had a starting-point, postulated the existence of "matter" to provide such starting-points. But the existence of this matter was a pure hypothesis; and matter is in actual fact as unobservable as the ether, Newtonian force and other unobservables which have vanished from science. Early science not only assumed matter to exist, but further pictured it as existing in space and time. Again this assumption had no adequate justification; for there is clearly no reason why the whole material universe should be restricted to the narrow framework along which messages strike our senses. To illustrate by an analogy, the earthquake waves which damage our houses travel along the surface of the ground, but we have no right to assume that they originate in the surface of the ground; we know, on the contrary, that they originate deep down in the earth's interior.

The Newtonian mechanics, however, having endowed space and time with real objective existences, assumed that the whole universe existed within the limits of space and time. Even more characteristic of it was the doctrine of "mechanistic determinism" which could be evolved from it by strictly logical processes. This reduced the whole physical universe to a vast machine in which each cog, shaft and thrust bar could only transmit what it received, and wait for what was to come next. When it was found that the human body consisted of nothing beyond commonplace atoms and molecules, the human race also seemed to be reduced to cogs in the wheel, and in face of the inexorable movements of the machine, human effort, initiative and ambition seemed to become meaningless illusions. Our minds were left with no more power or initiative than a sensitized cinematograph film; they could only register what was impressed on them from an outer world over which they had no control.

Theoretical physics is no longer concerned to study the Newtonian universe which it once believed to exist in its own right in space and time. It merely sets before itself the modest task of reducing to law and order the impressions that the universe makes on our senses. It is not concerned with what lies beyond the gateways of knowledge, but with what enters through the gateways of knowledge. It is concerned with appearances rather than reality, so that its task resembles that of the cartographer or map-maker rather than that of the geologist or mining engineer.

Now the cartographer knows that a map may be

drawn in many ways, or, as he would himself say, many kinds of projection are available. Each one has its merits, but it is impossible to find all the merits we might reasonably desire combined in one single map. It is reasonable to demand that each bit of territory should look its proper shape on the map; also that each should look its proper relative size. Yet even these very reasonable requirements can not usually be satisfied in a single map; the only exception is when the map is to contain only a small part of the whole surface of the globe. In this case, and this only, all the qualities we want can be combined in a single map, so that we simply ask for a map of the county of Surrey without specifying whether it is to be a Mercator's or orthographic or conic projection, or what not.

All this has its exact counterpart in the map-making task of the physicist. The Newtonian mechanics was like the map of Surrey, because it dealt only with a small fraction of the universe. It was concerned with the motions and changes of medium-sized objects—objects comparable in size with the human body—and for these it was able to provide a perfect map which combined in one picture all the qualities we could reasonably demand. But the inconceivably great and the inconceivably small were equally beyond its ken. As soon as science pushed out—to the cosmos as a whole in one direction and to sub-atomic phenomena in the other—the deficiencies of the Newtonian mechanics became manifest. And no modification of the Newtonian map was able to provide the two qualities which this map had itself encouraged us to expect—a materialism which exhibited the universe as constructed of matter lying within the framework of space and time, and a determinism which provided an answer to the question "What is going to happen next?"

When geography can not combine all the qualities we want in a single map, it provides us with more than one map. Theoretical physics has done the same, providing us with two maps which are commonly known as the particle-picture and the wave-picture.

The particle-picture is a materialistic picture which caters for those who wish to see their universe mapped out as matter existing in space and time. The wave-picture is a determinist picture which caters for those who ask the question "What is going to happen next?" It is perhaps better to speak of these two pictures as the particle-parable and the wave-parable. For this is what they really are, and the nomenclature warns us in advance not to be surprised at inconsistencies and contradictions.

Let me remind you, as briefly as possible, how this pair of pictures or parables have come to be in existence side by side.

The particle-parable, which was first in the field, told us that the material universe consists of particles existing in space and time. It was created by the labors of chemists and experimental physicists, working on the basis provided by the classical physics. Its time of testing came in 1913, when Bohr tried to find out whether the two particles of the hydrogen atom could possibly produce the highly complicated spectrum of hydrogen by their motion. He found a type of motion which could produce this spectrum down to its minutest details, but the motion was quite inconsistent with the mechanistic determinism of the Newtonian mechanics. The electron did not move continuously through space and time, but jumped, and its jumps were not governed by the laws of mechanics, but to all appearance, as Einstein showed more fully four years later, by the laws of probability. Of 1,000 identical atoms, 100 might make the jump, while the other 900 would not. Before the jumps occurred, there was nothing to show which atoms were going to jump. Thus the particle-picture conspicuously failed to provide an answer to the question, "What will happen next?"

Bohr's concepts were revolutionary, but it was soon found they were not revolutionary enough, for they failed to explain more complicated spectra, as well as certain other phenomena.

Then Heisenberg showed that the hydrogen spectrum—and, as we now believe, all other spectra as well—could be explained by the motion of something which was rather like an electron, but did not move in space and time. Its position was not specified by the usual coordinates x, y, z of coordinate geometry, but by the mathematical abstraction known as a matrix. His ideas were rather too abstract even for mathematicians, the majority of whom had quite forgotten what matrices were. It seemed likely that Heisenberg had unraveled the secret of the structure of matter, and yet his solution was so far removed from the concepts of ordinary life that another parable had to be invented to make it comprehensible.

The wave-parable serves this purpose; it does not describe the universe as a collection of particles but as a system of waves. "The universe is no longer a deluge of shot from a battery of machine-guns, but a stormy sea with the sea taken away and only the abstract quality of storminess left—or the grin of the Cheshire cat if we can think of a grin as undulatory." This parable was not devised by Heisenberg, but by de Broglie and Schrodinger. At first they thought their waves merely provided a superior model of an ordinary electron; later it was established that they were a sort of parable to explain Heisenberg's pseudo-electron.

Now the pseudo-electron of Heisenberg did not claim to account for the spectrum emitted by a single

atom of gas, which is something entirely beyond our knowledge or experience, but only that emitted by a whole assembly of similar atoms; it was not a picture of one electron in one atom, but of all the electrons in all the atoms.

In the same way the waves of the wave-parable do not picture individual electrons, but a community of electrons—a crowd—as, for instance, the electrons whose motion constitutes a current of electricity.

In this particular instance the waves can be represented as traveling through ordinary space. Except for traveling at a different speed, they are very like the waves by which Maxwell described the flow of radiation through space, so that matter and radiation are much more like one another in the new physics than they were in the old.

In other cases, ordinary time and space do not provide an adequate canvas for the wave-picture. The wave-picture of two currents of electricity, or even of two electrons moving independently, needs a larger canvas—six dimensions of space and one of time. There can be no logical justification for identifying any particular three of these six dimensions with ordinary space, so that we must regard the wave-picture as lying entirely outside space. The whole picture, and the manifold dimensions of space in which it is drawn, become pure mental constructs —diagrams and frameworks we make for ourselves to help us understand phenomena.

In this way we have the two coexistent pictures—the particle-picture for the materialist and the wave-picture for the determinist. When the cartographer has to make two distinct maps to exhibit the geography of, say, North America, he is able to explain why two maps are necessary, and can also tell us the relation between the two—he can show us how to transform one into the other. He will tell us, for instance, that he needs two maps simply because he is restricted to flat surfaces—pieces of paper. Give him a sphere instead, and he can show us North America, perfectly and completely, on a single map.

The physicist has not yet found anything corresponding to this sphere; when, if ever, he does, the particle-picture and the wave-picture will be merged into a single new picture. At present some kink in our minds, or perhaps merely some ingrained habit of thought, prevents our understanding the universe as a consistent whole—just as the ingrained habits of thought of a "flat-earther" prevents his understanding North America as a consistent whole. Yet, although physics has so far failed to explain why two pictures are necessary, it is, nevertheless, able to explain the relation between the particle-picture and the wave-picture in perfectly comprehensible terms.

The central feature of the particle-picture is the atomicity which is found in the structure of matter. But this atomicity is only one expression of a fundamental coarse-grainedness which pervades the whole of nature. It crops up again in the fact that energy can only be transferred by whole quanta. Because of this, the tools with which we study nature are themselves coarse-grained; we have only blunt probes at our disposal, and so can never acquire perfectly precise knowledge of nature. Just as, in astronomy, the grain of our photographic plates prevents our ever fixing the position of a star with absolute precision, so in physics we can never say that an electron is here, at this precise spot, and is moving at just such and such a speed. The best we can do with our blunt probes is to represent the position of the electron by a smear, and its motion by a moving smear which will get more and more blurred as time progresses. Unless we check the growth of our smear by taking new observations, it will end by spreading through the whole of space.

Now the waves on an electron or other piece of matter are simply a picture of just such a smear. Where the waves are intense, the smear is black, and conversely. The nature of the smear—whether it consists of printer's ink, or, as was at one time thought, of electricity—is of no importance; this is mere pictorial detail. All that is essential is the relative blackness of the smear at different places—a ratio of numbers which measures the relative chance of electrons being at different points of space.

The relation between the wave-picture and the particle-picture may be summed up thus: the more stormy the waves at any point in the wave-picture, the more likely we are to find a particle at that point in the particle-picture. Yet, if the particles really existed as points, and the waves depicted the chances of their existing at different points of space—as Maxwell's law does for the molecules of a gas—then the gas would emit a continuous spectrum instead of the line-spectrum that is actually observed. Thus we had better put our statement in the form that the electron is not a point-particle, but that if we insist on picturing it as such, then the waves indicate the relative proprieties of picturing it as existing at the different points of space. But propriety relative to what?

The answer is—relative to our own knowledge. If we know nothing about an electron except that it exists, all places are equally likely for it, so that its waves are uniformly spread through the whole of space. By experiment after experiment we can restrict the extent of its waves, but we can never reduce them to a point, or indeed below a certain minimum; the coarse-grainedness of our probes prevents that. There is always a finite region of waves left. And the waves which are left depict our knowledge precisely and exactly; we may say that they are waves

of knowledge—or, perhaps even better still, waves of imperfections of knowledge—of the position of the electron.

And now we come to the central and most surprising fact of the whole situation. I agree that it is still too early, and the situation is still too obscure, for us fully to assess its importance, but, as I see it, it seems likely to lead to radical changes in our views not only of the universe but even more of ourselves. Let us remember that we are dealing with a system of waves which depict in a graphic form our knowledge of the constituents of the universe. The central fact is this: the wave-parable does not tell us that these waves depict our knowledge of nature, but that they are nature itself.

If we ask the new physics to specify an electron for us, it does not give us a mathematical specification of an objective electron, but rather retorts with the question, "How much do you know about the electron in question?" We state all we know, and then comes the surprising reply, "That is the electron." The electron exists only in our minds—what exists beyond, and where, to put the idea of an electron into our minds we do not know. The new physics can provide us with wave-pictures depicting electrons about which we have varying amounts of knowledge, ranging from nothing at all to the maximum we can know with the blunt probes at our command, but the electron which exists apart from our study of it is quite beyond its purview.

Let me try and put this in another way. The old physics imagined it was studying an objective nature which had its own existence independently of the mind which perceived it—which, indeed, had existed from all eternity, whether it was perceived or not. It would have gone on imagining this to this day, had the electron observed by the physicists behaved as on this supposition it ought to have done.

But it did not so behave, and this led to the birth of the new physics, with its general thesis that the nature we study does not consist so much of something we perceive as of our perceptions; it is not the object of the subject-object relation, but the relation itself. There is, in fact, no clear-cut division between the subject and object; they form an indivisible whole which now becomes nature. This thesis finds its final expression in the wave-parable, which tells us that nature consists of waves and that these are of the general quality of waves of knowledge, or of absence of knowledge, in our own minds.

Let me digress to remind you that if ever we are to know the true nature of waves, these waves must consist of something we already have in our own minds. Now knowledge and absence of knowledge satisfy this criterion as few other things could; waves in an ether, for instance, emphatically did not. It may seem strange, and almost too good to be true, that nature should in the last resort consist of something we can really understand; but there is always the simple solution available that the external world is essentially of the same nature as mental ideas.

At best this may seem very academic and up in the air—at the worst it may seem stupid and even obvious. I agree that it would be so, were it not for the one outstanding fact that observation supports the wave-picture of the new physics whole-heartedly and without hesitation. Whenever the particle-picture and the wave-picture have come into conflict, observation has discredited the particle-picture and supported the wave-picture—not merely, be it noted, as a picture of our knowledge of nature, but as a picture of nature itself. The particle-parable is useful as a concession to the materialistic habits of thought which have become ingrained in our minds, but it can no longer claim to fit the facts, and, so far as we can at present see, the truth about nature must lie very near to the wave-parable.

Let me digress again to remind you of two simple instances of such conflicts and of the verdicts which observation has pronounced upon them.

A shower of parallel-moving electrons forms in effect an electric current. Let us shoot such a shower of electrons at a thin film of metal, as your own Professor G. P. Thomson did. The particle-parable compares it to a shower of hailstones falling on a crowd of umbrellas; we expect the electrons to get through somehow or anyhow and come out on the other side as a disordered mob. But the wave-parallel tells us that the shower of electrons is a train of waves. It must retain its wave-formation, not only in passing through the film, but also when it emerges on the other side. And this is what actually happens: it comes out and forms a wave-pattern which can be predicted—completely and perfectly—from its wave-picture before it entered the film.

Next let us shoot our shower of electrons against the barrier formed by an adverse electromotive force. If the electrons of the shower have a uniform energy of ten volts each, let us throw them against an adverse potential difference of a million volts. According to the particle-parable, it is like throwing a handful of shot up into the air; they will all fall back to earth in time—the conservation of energy will see to that. But the wave-parable again sees our shower of electrons as a train of waves—like a beam of light—and sees the potential barrier as an obstructing layer—like a dirty window pane. The wave-parable tells us that this will check, but not entirely stop, our beam of electrons. It even shows us how to calculate what fraction will get through. And just this fraction, in

actual fact, does get through; a certain number of ten-volt electrons surmount the potential barrier of a million volts—as though a few of the shot thrown lightly up from our hands were to surmount the earth's gravitational field and wander off into space. The phenomenon appears to be in flat contradiction to the law of conservation of energy, but we must remember that waves of knowledge are not likely to own allegiance to this law.

A further problem arises out of this experiment. Of the millions of electrons of the original shower, which particular electrons will get through the obstacle? Is it those who get off the mark first or those with the highest turn of speed or what? What little extra have they that the others haven't got?

It seems to be nothing more than pure good luck. We know of no way of increasing the chances of individual electrons; each just takes its turn with the rest. It is a concept with which science has been familiar ever since Rutherford and Soddy gave us the law of spontaneous disintegration of radioactive substances—of a million atoms ten broke up every year, and no help we could give to a selected ten would cause fate to select them rather than the ten of her own choosing. It was the same with Bohr's model of the atom; Einstein found that without the caprices of fate it was impossible to explain the ordinary spectrum of a hot body; call on fate, and we at once obtained Planck's formula, which agrees exactly with observation.

From the dawn of human history, man has been wont to attribute the results of his own incompetence to the interference of a malign fate. The particle-picture seems to make fate even more powerful and more all-pervading than ever before; she not only has her finger in human affairs, but also in every atom in the universe. The new physics has got rid of mechanistic determinism, but only at the price of getting rid of the uniformity of nature as well!

I do not suppose that any serious scientist feels that such a statement must be accepted as final; certainly I do not. I think the analogy of the beam of light falling on the dirty window-pane will show us the fallacy of it.

Heisenberg's mathematical equation shows that the energy of a beam of light must always be an integral number of quanta. We have observational evidence of this in the photoelectric effect, in which atoms always suffer damage by whole quanta.

Now this is often stated in parable form. The parable tells us that light consists of discrete light-particles, called photons, each carrying a single quantum of energy. A beam of light becomes a shower of photons moving through space like the bullets from a machine-gun; it is easy to see why they necessarily do damage by whole quanta.

When a shower of photons falls on a dirty window-pane, some of the photons are captured by the dirt, while the rest escape capture and get through. And again the question arises: How are the lucky photons singled out? The obvious superficial answer is a wave of the hand towards fortune's wheel; it is the same answer that Newton gave when he spoke of his "corpuscles of light" experiencing alternating fits of transmission and reflection. But we readily see that such an answer is superficial.

Our balance at the bank always consists of an integral number of pence, but it does not follow that it is a pile of bronze pennies. A child may, however, picture it as so being, and ask his father what determines which particular pennies go to pay the rent. The father may answer "Mere chance"—a foolish answer, but no more foolish than the question. Our question as to what determines which photons get through is, I think, of a similar kind, and if nature seems to answer "Mere chance," she is merely answering us according to our folly. A parable which replaces radiation by identifiable photons can find nothing but the finger of fate to separate the sheep from the goats. But the finger of fate, like the photons themselves, is mere pictorial detail. As soon as we abandon our picture of radiation as a shower of photons, there is no chance but complete determinism in its flow. And the same is, I think, true when the particle-photons are replaced by particle-electrons.

We know that every electric current must transfer electricity by complete electron-units, but this does not entitle us to replace an electric current by a shower of identifiable electron-particles. Indeed the exclusion-principle of Pauli, which is in full agreement with observation, definitely forbids our doing so. When the red and white balls collide on a billiard table, red may go to the right and white to the left. The collision of two electrons A and B is governed by similar laws of energy and momentum, so that we might expect to be able to say that A goes to the right, and B to the left or *vice versa*. Actually we must say no such thing, because we have no right to identify the two electrons which emerge from the collision with the two that went in. It is as though A and B had temporarily combined into a single drop of electric fluid, which had subsequently broken up into two new electrons, C, D. We can only say that after the collision C will go to the right, and D to the left. If we are asked which way A will go, the true answer is that by then A will no longer exist. The superficial answer is that it is a pure toss-up. But the toss-up is not in nature, but in our own minds; it is an even chance whether we choose to identify C with A or with B.

Thus the indeterminism of the particle-picture seems to reside in our own minds rather than in nature. In any case this picture is imperfect, since it fails to rep-

resent the facts of observation. The wave-picture, which observation confirms in every known experiment, exhibits a complete determinism.

Again we may begin to feel that the new physics is little better than the old—that it has merely replaced one determinism by another. It has; but there is all the difference in the world between the two determinisms. For in the old physics the perceiving mind was a spectator; in the new it is an actor. Nature no longer forms a closed system detached from the perceiving mind; the perceiver and perceived are interacting parts of a single system. The nature depicted by the wave-picture in some way embraces our minds as well as inanimate matter. Things still change solely as they are compelled, but it no longer seems impossible that part of the compulsion may originate in our own minds.

Even the inadequate particle-picture told us something very similar in its own roundabout stammering way. At first it seemed to be telling us of a nature distinct from our minds, which moved as directed by throws of the dice, and then it transpired that the dice were thrown by our own minds. Our minds enter into both pictures, although in somewhat different capacities. In the particle-picture the mind merely decides under what conventions the map is to be drawn; in the wave-picture it perceives and observes and draws the map. We should notice, however, that the mind enters both pictures only in its capacity as a receptacle—never as an emitter.

The determinism which appears in the new physics is one of waves, and so, in the last resort, of knowledge. Where we are not ourselves concerned, we can say that event follows event; where we are concerned, only that knowledge follows knowledge. And even this knowledge is one only of probabilities and not of certainties; it is at best a smeared picture of the clear-cut reality which we believe to lie beneath. And just because of this, it is impossible to decide whether the determinism of the wave-picture originates in the underlying reality or not—Can our minds change what is happening in reality, or can they only make it look different to us by changing our angle of vision? We do not know, and as I do not see how we can ever find out, my own opinion is that the problem of free will will continue to provide material for fruitless discussion until the end of eternity.

The contribution of the new physics to this problem is not that it has given a decision on a long-debated question, but that it has reopened a door which the old physics had seemed to slam and bolt. We have an intuitive belief that we can choose our lunch from the menu or abstain from housebreaking or murder; and that by our own volition we can develop our freedom to choose. We may, of course, be wrong. The old physics seemed to tell us that we were, and that our imagined freedom was all an illusion; the new physics tells us it may not be.

The old physics showed us a universe which looked more like a prison than a dwelling-place. The new physics shows us a building which is certainly more spacious, although its interior doors may be either open or locked—we can not say. But we begin to suspect it may give us room for such freedom as we have always believed we possessed; it seems possible at least that in it we can mould events to our desire, and live lives of emotion, intellect and endeavor. It looks as though it might form a suitable dwelling-place for man, and not a mere shelter for brutes.

The new physics obviously carries many philosophical implications, but these are not easy to describe in words. They can not be summed up in the crisp, snappy sentences beloved of scientific journalism, such as that materialism is dead or that matter is no more. The situation is rather that both materialism and matter need to be redefined in the light of our new knowledge. When this has been done, the materialist must decide for himself whether the only kind of materialism which science now permits can be suitably labelled materialism, and whether what remains of matter should be labelled as matter or as something else; it is mainly a question of terminology.

What remains is in any case very different from the full-blooded matter and the forbidding materialism of the Victorian scientist. His objective and material universe is proved to consist of little more than constructs of our own minds. To this extent, then, modern physics has moved in the direction of philosophic idealism. Mind and matter, if not proved to be of similar nature, are at least found to be ingredients of one single system. There is no longer room for the kind of dualism which has haunted philosophy since the days of Descartes.

This brings us at once face to face with the fundamental difficulty which confronts every form of philosophical idealism. If the nature we study consists so largely of our own mental constructs, why do our many minds all construct one and the same nature? Why, in brief, do we all see the same sun, moon and stars?

I would suggest that physics itself may provide a possible although very conjectural clue. The old particle-picture which lay within the limits of space and time broke matter up into a crowd of distinct particles, and radiation into a shower of distinct photons. The newer and more accurate wave-picture, which transcends the frame-work of space and time, recombines the photons into a single beam of light and the shower of parallel-moving electrons into a continuous electric current. Atomicity and division into individual existences are fundamental in the restricted space-time picture, but disappear in the wider, and as far

as we know more truthful, picture which transcends space and time. In this, atomicity is replaced by what General Smuts would describe as "holism"—the photons are no longer distinct individuals each going its own way, but members of a single organization or whole—a beam of light. The same is true, *mutatis mutandis,* of the electrons of a parallel-moving shower. The biologists are beginning to tell us, although not very unanimously, that the same may be true of the cells of our bodies. And is it not conceivable that what is true of the objects perceived may be true also of the perceiving minds? When we view ourselves in space and time we are quite obviously distinct individuals; when we pass beyond space and time we may perhaps form ingredients of a continuous stream of life. It is only a step from this to a solution of the problem which would have commended itself to many philosophers, from Plato to Berkeley, and is, I think, directly in line with the new world-picture of modern physics.

I have left but little time to discuss affairs of a more concrete nature. We meet in a year which has to some extent seen science arraigned before the bar of public opinion; there are many who attribute most of our present national woes—including unemployment in industry and the danger of war—to the recent rapid advance in scientific knowledge.

Even if their most lurid suspicions were justified, it is not clear what we could do. For it is obvious that the country which called a halt to scientific progress would soon fall behind in every other respect as well—in its industry, in its economic position, in its naval and military defenses and, not least important, in its culture. Those who sigh for an Arcadia in which all machinery would be scrapped and all invention proclaimed a crime, as it was in Erewhon, forget that the Erewhonians had neither to compete with highly organized scientific competitors for the trade of the world nor to protect themselves against possible bomb-dropping, blockade or invasion.

But can we admit that the suspicions of our critics are justified? If science has made the attack more deadly in war, it has also made the defense more efficient in the long run; it shows no partiality in the age-long race between weapons of attack and defense. This being so, it would, I think, be hard to maintain in cold blood that its activities are likely to make wars either more frequent or more prolonged. It is at least arguable that the more deadly a war is likely to be, the less likely it is to occur.

Still it may occur. We can not ignore the tragic fact that, as our president of two years ago told us, science has given man control over nature before he has gained control over himself. The tragedy does not lie in man's scientific control over nature but in his absence of moral control over himself. This is only one chapter of a long story—human nature changes very slowly, and so forever lags behind human knowledge, which accumulates very rapidly. The plays of Aeschylus and Sophocles still thrill us with their vital human interest, but the scientific writings of Aristarchus and Ptolemy are dead—mere historical curiosities which leave us cold. Scientific knowledge is transmitted from one generation to another, while acquired characteristics are not. Thus, in respect of knowledge, each generation stands on the shoulders of its predecessor, but in respect of human nature, both stand on the same ground.

These are hard facts which we can not hope to alter, and which—we may as well admit—may wreck civilization. If there is an avenue of escape, it does not, as I see it, lie in the direction of less science, but of more science—psychology, which holds out hopes that, for the first time in his long history, man may be enabled to obey the command "Know thyself"; to which I, for one, would like to see adjoined a morality and, if possible, even a religion, consistent with our new psychological knowledge and the established facts of science; scientific and constructive measures of eugenics and birth control; scientific research in agriculture and industry, sufficient at least to defeat the gloomy prophecies of Malthus and enable ever larger populations to live in comfort and contentment on the same limited area of land. In such ways we may hope to restrain the pressure of population and the urge for expansion which, to my mind, are far more likely to drive the people of a nation to war than the knowledge that they—and also the enemies they will have to fight—are armed with the deadliest weapons which science can devise.

This last brings us to the thorny problem of economic depression and unemployment. No doubt a large part of this results from the war, national rivalries, tariff barriers and various causes which have nothing to do with science, but a residue must be traced to scientific research; this produces labor-saving devices which in times of depression are only too likely to be welcomed as wage-saving devices and to put men out of work. The scientific Robot in *Punch's* cartoon boasted that he could do the work of 100 men, but gave no answer to the question—"Who will find work for the displaced 99?" He might, I think, have answered—"The pure scientist, in part at least." For scientific research has two products of industrial importance—the labor-saving inventions which displace labor, and the more fundamental discoveries which originate as pure science, but may ultimately lead to new trades and new popular demands providing employment for vast armies of labor.

Both are rich gifts from science to the community. The labor-saving devices lead to emancipation from soul-destroying toil and routine work, to greater

leisure and better opportunities for its enjoyment. The new inventions add to the comfort and pleasure, health and wealth of the community. If a perfect balance could be maintained between the two, there would be employment for all, with a continual increase in the comfort and dignity of life. But, as I see it, troubles are bound to arise if the balance is not maintained, and a steady flow of labor-saving devices, with no accompanying steady flow of new industries to absorb the labor they displace, can not but lead to unemployment and chaos in the field of labor. At present we have a want of balance resulting in unemployment, so that our great need at the moment is for industry-making discoveries. Let us remember Faraday's electromagnetic induction, Maxwell's Hertzian waves, and the Otto cycle—each of which has provided employment for millions of men. And, although it is an old story, let us also remember that the economic value of the work of one scientist alone, Edison, has been estimated at three thousand million pounds.

Unhappily, no amount of planning can arrange a perfect balance. For as the wind bloweth where it listeth, so no one can control the direction in which science will advance; the investigator in pure science does not know himself whether his researches will result in a mere labor-saving device or a new industry. He only knows that if all science were throttled down, neither would result; the community would become crystallized in its present state, with nothing to do but watch its population increase, and shiver as it waited for the famine, pestilence or war which must inevitably come to restore the balance between food and mouths, land and population.

Is it not better to press on in our efforts to secure more wealth and leisure and dignity of life for our own and future generations, even though we risk a glorious failure, rather than accept inglorious failure by perpetuating our present conditions, in which these advantages are the exception rather than the rule? Shall we not risk the fate of that over-ambitious scientist Icarus, rather than resign ourselves without an effort to the fate which has befallen the bees and ants? Such are the questions I would put to those who maintain that science is harmful to the race.

SCIENTIFIC EVENTS

THE SIXTH INTERNATIONAL BOTANICAL CONGRESS

THE Organizing Committee of the Sixth International Botanical Congress, meeting in Amsterdam, from September 2 to 7, 1935, announces that the following topics have been chosen tentatively for discussion in the sections:

Agronomy. Interactions between roots and soil; interactions between plants. Virus diseases. Weed flora as an indicator of soil conditions in agriculture. Grassland associations. Genetics and breeding of immune varieties. Inbreeding. Importance of microbiological investigations in the study of agricultural problems. Influencing the cycle of development in plants.

Cytology. Structure of chromosomes. Crossing-over versus conversion. Terminology of cytology and genetics. Pairing of chromosomes in polyploids. Reduction division in fungi. Chain- and ring-formation of chromosomes. Submicroscopical structure of the cell wall. Vacuome, chondriome, plastids. Colloid chemistry of protoplasm; vital staining.

Genetics. Experimental mutations. Genetical basis of size and form. Crossing-over versus conversion. Terminology of cytology and genetics. Sexuality in fungi. Reduction division in fungi. Genetics and breeding of immune varieties. Inbreeding. Taxonomy and genetics. Plasm and genotype in their mutual relations. Lethal factors.

Geobotany, Ecology and Phytogeography. Climax associations in Northwestern Europe and North America. Cartography: vegetation maps; area maps. Flora and vegetation area. Plant geography in younger formations. The halophyte problem. Classification and nomenclature of vegetation units. Miscellaneous papers.

Morphology and Anatomy. Size and form. Genetical basis of size and form. Phyto hormones; general paper. Leaf arrangements. Flower morphology. Female fructification and phylogeny of Conifers. Wood anatomy. Relations between anatomy and external morphology. Morphology of Bryophytes.

Mycology and Bacteriology. Differential characters in Hymenomycetes. Nomenclature of fungi. Sexuality in fungi. Reduction division in fungi. Biologic forms of fungi. Importance of microbiological investigations in the study of agricultural problems. Phylogeny and taxonomy of Phycomycetes.

Phytopathology. Biological basis of plant quarantine. Virus diseases. Various papers. Biologic forms of fungi. Immunization. Physiologic diseases.

Paleobotany. Geobotanical provinces in the older formations. Caytoniales and Pteridospermae and the evolution of Angiosperms. Flower morphology. Plant geography in younger formations. Synchronism and uniformity in paleozoic and mesozoic floras. Various papers.

Plant Physiology. Photosynthesis. Phyto hormones; general paper. Phyto hormones; various papers. Oxidation, reduction and metabolism. Permeability and the accumulation of mineral elements. Submicroscopical structure of the cell wall. Translocation of plastic materials. Influencing the cycle of development in plants.

Taxonomy and Nomenclature. Various papers. Cay-

toniales and Pteridospermae and the evolution of Angiosperms. Flower morphology. Female fructification and phylogeny of Conifers. Taxonomy and genetics. Phylogeny and taxonomy of Phycomycetes.

ECONOMICS AND THE SOCIAL SCIENCES AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

A NEW departure in technological training to meet a growing demand for engineers with a thorough understanding of the social and economic implications of their profession has been announced by President Karl T. Compton, of the Massachusetts Institute of Technology. The institute will offer a new five-year course which will include advanced studies in the social sciences and economics. This course, which in no way affects the regular four-year courses in science and engineering, has been approved by the faculty and the corporation. It will be offered next autumn in nearly all the professional fields of the curriculum.

In the announcement Dr. Compton says:

The new course will include essentially the same professional studies as at present in any one of the departments of engineering or science, but will also include an increasing program of more advanced studies in the fields of economics and the social sciences running through the last three years of the five-year course. In the fifth year a considerable amount of time will be devoted to a thesis on some subject which combines the professional and economic aspects of the problem which is chosen. On satisfactory completion of the fifth year there will be awarded the degree of bachelor of science in the professional field, such as civil or electrical or mechanical engineering, or chemistry or physics or biology, and also the degree of master of science in economics and engineering.

It was General Francis A. Walker, as former president of the Massachusetts Institute of Technology, who first had a clear vision of the coming economic importance of the engineer's work and reduced this vision to practise by the introduction of economic studies into the regular program of professional training at this institution. Later, under the influence of Professor Davis R. Dewey, an offshoot of this work in economics developed into the present important and flourishing department of business and engineering administration.

It is our conviction that the five-year course now being established represents another important step in the training of men in applied science, with a realization of the social implications of their work. It will constitute an introduction to the ideas and techniques through which the social and economic effects of engineering are woven into the complex pattern of our present civilization.

THE BELTSVILLE RESEARCH CENTER

SECRETARY WALLACE has formally designated the field activities at Beltsville and at Bell, Md., as the "Beltsville Research Center of the Department of Agriculture" and has named Dr. E. N. Bressman as temporary director. This action brings together under one administrative head most of the field activities of the department in the vicinity of Washington. It is planned to develop the Beltsville Research Center, comprising about 4,500 acres, about 15 miles northeast of Washington, as the principal experimental area under control of the department and as the largest and most completely equipped plant for the scientific study of agriculture in this country.

Already ten bureaus of the department are conducting or are definitely planning activities in this area. The policy of the department will be to continue concentrating all the field work of this nature at Beltsville. The new center will be organized to control the whole area and will include the plant introduction garden at Bell.

Buildings have been erected during the last year or two, both as a part of the regular program of the department and more recently under several emergency funds for stimulating employment. Additional buildings will be required to house activities that will be shifted to this area as conditions make the moves desirable.

The director of the center will represent both the secretary and the chiefs of the various bureaus engaged in work at the center. He is charged with "continued development and coordination of the Research Center on a comprehensive and orderly plan," and will have custody of and control the assignment of lands, building equipment to promote efficient use of facilities for maximum service and economy of operation of the center as a whole.

The ten bureaus now assigned to conduct work in this area are: the Bureaus of Animal Industry, Plant Industry, Dairy Industry, Agricultural Engineering, Entomology and Plant Quarantine, Chemistry and Soils, Agricultural Economics and Biological Survey, and the Food and Drug Administration and the Forest Service. Other departments of the government also have some activities at the research center. It is planned ultimately to move to Beltsville many of the activities which have been under way at the Arlington Experimental Farm just south of Washington.

Starting years ago primarily as a farm where the Bureau of Animal Industry could keep animals required for its research, the area has developed because in one line of work after another the need has been felt to take the laboratory to the field. For practical value, too, the concentration of varied lines of research in one area is desirable because it runs more nearly parallel to farm experience where crops are planned as feed for animals. Research at Beltsville in genetics and in long-term programs of breeding for improvement of beef and dairy cattle, swine, sheep

and other animals and for study of animal diseases and parasites has required the expansion of the original farm, and the area required to maintain the larger herds may be used at the same time in many of the other lines of research not directly connected with the work with animals.

In recent years the department has increased its cooperative work with many of the State Experiment Stations—as in the large-scale studies of methods of feeding beef animals for quality—and the Beltsville center has served as a place for comparing the results of experimental feeding all over the country.

THE AMERICAN STANDARDS ASSOCIATION

DR. P. G. AGNEW, secretary of the American Standards Association, reports that membership has increased to 42 member-bodies and associate members and 1,233 company members; since January, nine associations have become member-bodies or associate members.

The American Standards Association is the national clearing house for standards and safety codes. It was formed in 1918 by five technical societies which felt the need of developing inter-industry standards out of their own technical standards.

More than 250 codes have been developed by the association, and nearly 200 are under development or are being revised. More than 3,000 engineers, scientific men and industrialists, representing manufacturers, technical societies, consumers and government departments, serve on its numerous committees.

The National Electrical Manufacturers Association, and the Casualty Group of the American Mutual Alliance, have increased their memberships to make available the facilities and services of the American Standards Association to all of their members. Six hundred and seventy-three companies are represented by these groups.

During this period, eleven other companies have joined the association, and four corporations have voluntarily increased their dues.

The American Petroleum Institute, the National Association of Master Plumbers of the United States and the American Institute of Bolt, Nut and Rivet Manufacturers are the new member-bodies.

Associate member affiliations include the Illuminating Engineering Society, the American Hospital Association, the Society of Motion Picture Engineers, the Library Group, which consists of the American Library Association and the Special Libraries Association, the American Water Works Association and the Grinding Wheel Manufacturers Association of the United States.

New company members that have joined since the first of the year are E. I. du Pont de Nemours and Company, the Electric Bond and Share Company, the Foxboro Company, Gilbert and Barker Manufacturing Company, the Texas Cities Gas Company, the Wright Aeronautical Corporation, the Fellows Gear Shaper Company, the Neville Company, John Barth and Company, the O. K. Tool Company and the Carrier Corporation.

The following have been appointed members of the Advisory Committee: George B. Cortelyou, president of the Consolidated Gas Company, who served as Postmaster General and later as Secretary of the Treasury; Sewell L. Avery, chairman of the board, Montgomery Ward & Company, and president of the U. S. Gypsum Company; Lammot du Pont, president of E. I. du Pont de Nemours & Company, and chairman of the General Motors Corporation; Walter S. Gifford, president of the American Telephone and Telegraph Company; Henry I. Harriman, president of the Chamber of Commerce of the United States; W. A. Irvin, president of the U. S. Steel Corporation; James H. McGraw, chairman of the board, McGraw-Hill Publishing Company; Gerard Swope, president of the General Electric Company; Daniel Willard, president of the Baltimore & Ohio Railroad.

THE NEW YORK MEETING OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION

THE forty-second annual meeting of the American Psychological Association was held at Columbia University on September 5, 6, 7 and 8, under the presidency of Dr. Joseph Peterson, chairman of the department of psychology at the George Peabody College for Teachers, Nashville, Tenn. Dr. Peterson's address was entitled "Aspects of Learning."

The association held twenty-four sessions, which, with their presiding officers, were as follows:

General: Joseph Peterson, George Peabody College for Teachers.

Mental Tests: J. McKeen Cattell, New York.

Aesthetics: H. L. Hollingworth, Columbia University.

Sensation and Perception: Walter B. Pillsbury, University of Michigan.

Clinical Psychology: Robert S. Woodworth, Columbia University.

Animal Psychology: Dr. Robert M. Yerkes, Yale University; Walter S. Hunter, Clark University; Leonard Carmichael, Brown University; Harvey Carr, University of Chicago; John E. Anderson, University of Minnesota.

Vocational Psychology: Edward L. Thorndike, Columbia University.

Galvanometric Studies: Knight Dunlap, The Johns Hopkins University.

Child Development: Walter R. Miles, Yale University.

Personality Measurement: Henry E. Garrett, Columbia University.

Physiological Psychology: Calvin P. Stone, Stanford University; Edward A. Bott, University of Toronto.

Abnormal Psychology: Joseph Jastrow, New York.

Instructional Films: Walter R. Miles, Yale University.

Research Films: Joseph Peterson, George Peabody College for Teachers.

Memory and Learning: A. T. Poffenberger, Columbia University.

Personality and Character: Lewis M. Terman, Stanford University.

Student Personnel: Harold E. Burtt, The Ohio State University.

Sensation and Perception: Edward S. Robinson, Yale University.

Child Psychology: Florence L. Goodenough, University of Minnesota.

Three round tables were arranged for September 7 as follows:

Problems in Clinical Psychology: Edgar A. Doll, *chairman.*

Instructional Films: Walter R. Miles, *chairman.*

Use of Electric Shock in Psychological Experimentation: G. R. Wendt, *chairman.*

SCIENTIFIC NOTES AND NEWS

DR. ARTHUR H. COMPTON, professor of physics at the University of Chicago, is this year George Eastman visiting professor at the University of Oxford, where he will spend six months. He sailed for Europe on August 3. Prior to his visit to Oxford Dr. Compton planned to attend the first International Congress of Electro-Radio-Biology, held in Venice from September 10 to 15, and the Congress of the International Union of Pure and Applied Physics in London from October 1 to 6.

AT the conclusion of the address of Dr. Charles L. Reese, president of the American Chemical Society, to be given at Cleveland on September 10, the society's award in pure chemistry will be presented to Dr. C. Frederick Koelsch, of the University of Minnesota, who will make an address before the division of organic chemistry on "A Cyclic α-Diketone." The award, founded by A. C. Langmuir, is a prize of a thousand dollars given to an American chemist under thirty years of age.

PAUL F. NICHOLS, associate in fruit products at the College of Agriculture of the University of California, has been made Chevalier du Mérite Agricole by the French Government in recognition of his services to the fruit and vegetable drying, processing and manufacturing industries.

DR. WILDER PENFIELD, clinical professor of neurological surgery, McGill University Faculty of Medicine, received a ceremonial chalice at the twenty-first reunion of the class of 1913 of Princeton University. The chalice has been dedicated by the class to commemorate outstanding accomplishments of its members and will be retained by Dr. Penfield until another award is made.

THE University of Sheffield recently conferred the honorary degree of doctor of science on Professor Emeritus William Palmer Wynne, of the department of chemistry, and on Professor Emeritus Edward Mellanby, of the department of pharmacology.

THE "Adlerschild" of the German Empire has been awarded to Dr. Adolf Schmidt, of Gotha, formerly director of the Meteorological Magnetic Observatory at Potsdam.

Nature reports that Dr. Minoru Mashino, a research chemist in the Tokyo Imperial Industrial Research Laboratory, has been awarded the medal for "special merit in research" of the Society of Chemical Industry, Japan, for his work on the proteins of the soya bean.

DR. CARL R. MOORE, professor of zoology at the University of Chicago, has been made chairman of the department of zoology, succeeding Dr. C. M. Child, who will become professor emeritus on October 1.

DR. GUY-HAROLD SMITH will assume the chairmanship of the department of geography at the Ohio State University on October 1. He will succeed Professor C. C. Huntington, who has retired on the occasion of completing twenty-five years service to the university. He has been chairman of the department since it was organized in 1922 and will continue as professor of geography.

PROFESSOR JAMES E. RICE, head of the poultry department of the New York State College of Agriculture at Cornell University since its establishment in 1905, has retired from active service.

PROMOTIONS at the University of California School of Medicine include Dr. Edward L. Munson, to a professorship of preventive medicine, and Dr. Keene O. Haldeman, to an assistant clinical professorship of orthopedic surgery.

PROFESSOR GEORGE LYNN CROSS, of the University of South Dakota, has accepted an appointment to the staff of the department of botany at the University of Oklahoma. In addition to other work he will have charge of courses in plant anatomy and morphology, heretofore taught by Dr. A. S. Foster, who has joined the staff of the University of California.

DR. PAUL R. BURKHOLDER, formerly of the Buffalo Museum of Natural History and this past year a National Research Fellow at Columbia University, has been appointed a member of the staff of the department of botany at Connecticut College, New London. Dr. Harriet Creighton, instructor in cytology at Cornell University, has been appointed to an instructorship.

AT the Massachusetts State College, Ronald L. Mighell, assistant research professor of farm management, has been made acting head of the department of farm management. Dr. Nathan Rakieten, of New Haven, last year Porter fellow in physiology of the American Physiological Society, has been appointed instructor in physiology.

DR. WALTER M. FUCHS, formerly professor at the Technische Hochschule, Aachen, Germany, was recently appointed research professor at Rutgers University.

DR. PAUL HARTECK, of the University of Berlin, has been appointed professor of physical chemistry at the University of Hamburg.

PROFESSOR F. N. MOWDAWALLA, who recently resigned his appointment as professor of electrical technology in the Indian Institute of Science, Bangalore, has been appointed principal and professor of electrical engineering of the University College of Engineering, Bangalore.

HARRY ALFRED NOYES, research chemist and food technologist of the New Rochelle, N. Y., Research Laboratory, has been appointed managing director of the Applied Sugar Laboratories.

ACCORDING to *Industrial and Engineering Chemistry*, A. H. Maude has resigned his position as chemical engineer with the Atmospheric Nitrogen Corporation and has accepted a similar post with the National Aniline and Chemical Company at Buffalo, N. Y. Mr. Maude was formerly chemical engineer with the Rubber Service Laboratories Company, Nitro, W. Va.

DR. ROBERT A. H. MACKEEN, assistant professor of pathology and bacteriology on the Dalhousie University Faculty of Medicine, Halifax, Nova Scotia, and assistant pathologist for the province, has been appointed director of the Bureau of Laboratories of the Province of New Brunswick.

DR. ENRIQUE BELTRAN, professor of zoology at the University of Mexico, was appointed to the directorship of the newly created Instituto Biotecnico which is devoted to routine and research work in the field of agriculture, forestry, animal husbandry and fisheries.

PROFESSOR BERNHARD ZONDEK, formerly head of the department of gynecology of the Charity Hospital in Berlin, has been appointed to direct the departments of obstetrics and gynecology of the Hadassah-Rothschild Hospital at Jerusalem.

IN the reorganization of the Southern Forest Experiment Station, V. L. Harper has been placed in charge of silvicultural research in the naval stores region of the southeast, and H. G. Meginnis in charge of erosion-streamflow investigations now largely concentrated in the Mississippi bluffands. W. G. Wahlenberg has been transferred from forest management investigations to forest economics in place of A. E. Wackerman, recently resigned, and his place has been taken by E. W. Gemmer. Roy A. Chapman, who has been on special assignments, has been given charge of work in forest measurements.

The Experiment Station Record states that at the Washington College and Experiment Station, Rex E. Willard, head of the department of farm management and agricultural economics, has leave of absence for one year to become regional director of the Pacific Northwest Planning Division of the Agricultural Adjustment Administration. His territory will include Washington, Oregon and Idaho, with headquarters at Washington College.

ELDON B. ENGLE, assistant professor of soils at the University of Nebraska, has been given a year's leave of absence to accept a position with the Soil Erosion Service, U. S. Department of the Interior. Harold Hedges, research associate in rural economics, has also been granted a year's leave of absence, beginning on July 1, for the purpose of acting as secretary of the Bank for Cooperatives at Omaha.

F. R. WILCOX, extension specialist in marketing for the College of Agriculture, University of California, has been elected permanent chairman of the California Prune Control Board. The board administers the marketing agreement and license covering all handlers of California prunes.

DR. OLIN WEST, Chicago, secretary of the American Medical Association, addressed a scientific session of the Idaho State Medical Association, meeting at Lewiston on September 7. He also spoke at the annual banquet in the evening.

DR. JAMES BRYANT CONANT, president of Harvard University, has returned after spending two months in Europe.

THE leave of absence of L. E. Call, dean of the division of agriculture and director of the Kansas State College and Experiment Station, has been extended to December, in order that he may continue to serve as president of the Federal Land Bank at Wichita.

PROFESSOR WILLIAM H. STEVENSON, vice-director of the Agricultural Experiment Station at the Iowa

State College, has been appointed delegate of the United States at the autumn meeting of the International Institute of Agriculture in Rome. Dr. Rexford G. Tugwell, Assistant Secretary of Agriculture, has been designated as alternate delegate.

Curator Frank E. Lutz and E. L. Bell, of the American Museum of Natural History, and two volunteer assistants spent the summer in southwestern Colorado and northern Arizona for the purpose of collecting and making observations upon the insects of the region. Their work took them to the bottom of the Grand Canyon and to the tree-line near the tops of near-by mountains.

Templeton Crocker is leaving San Francisco on September 15 on the *Zaca* for a scientific expedition to southeastern Polynesia, accompanied by Dr. H. L. Shapiro, Dr. James P. Chapin and Francis L. Jaques, all from the American Museum of Natural History. The itinerary is expected to include the Marquesas, Tuamotus, Tahiti, Rapa, Mangareva, Pitcairn Island, Easter Island and several islands off the coast of South America, as well as the Galapagos Islands. Dr. Chapin and Mr. Jaques will collect material for habitat groups of oceanic birds, while Dr. Shapiro will continue his studies of Polynesian peoples. The Pitcairn Islanders will be a particular object for his genetic researches on the descendants of the mutineers of the *Bounty*.

The nineteenth annual meeting of the Optical Society of America will be held from October 18 to 20 at the National Bureau of Standards, Washington, D. C. In addition to the usual program of papers contributed by members on their own initiative, the meeting will include the following special features: (1) An exhibition of instruments and products in which the application of optical principles plays an important part in their design, construction or use. The exhibit will be in the same building in which the meetings are held and will be open one evening as well as during the day; (2) an evening visit to the Naval Observatory with an opportunity to inspect its equipment and in particular the new Ritchey-Chrétien 40-inch photographic reflector; (3) a session devoted to "Optics of Astronomical Instruments."

The Genetics Society of America held a meeting at the Marine Biological Laboratory, Woods Hole, on August 22 and 23. In the absence of the presiding officers, Professor John H. Gerould acted as chairman for the morning sessions at which sixteen papers were read. There was an attendance of about seventy-five, of whom forty-one were members of the society. Wednesday afternoon was devoted to informal discussion with twelve demonstrations of genetic and cytological material. Much interest centered about conditions in the egg bearing on genetic problems. About seventy attended the shore dinner and beach party at Sippiwisset. The symposium on Thursday afternoon on "Genetics and Development," with Professor E. G. Conklin presiding, consisted of papers by Drs. Emil Witschi, B. H. Willier, J. L. Cartledge and P. W. Whiting. The Marine Biological Laboratory arranged programs of interest to geneticists on evenings preceding and following the meetings of the society.

The eighth Congress of the French Societies of Oto-Neuro-ophthalmology, which was to have been held at Barcelona this year, has been postponed to next Easter, when it will probably be held at Nice.

Weekly lectures in the sciences underlying the practise of horticulture will be resumed on October 1 in the course for professional gardeners given by the New York Botanical Garden. Advance registrations will be received by Dr. Forman T. McLean, director of the course, at the New York Botanical Garden. The original aim of this course was to give proper training to the younger gardeners at the institution. Its scope was later extended. Enrolment is restricted, however, to those who have had several years of continuous and successful experience with plants. A knowledge of the common garden and greenhouse subjects is assumed for each student. Most of the lectures are given by the staff of the New York Botanical Garden, all of whom volunteer their services. First-year men study the structure, relationships, habits, functions and classification of plants. Laboratory work is included in the second half year. The subjects of the advanced courses include soils and fertilizers, entomology, plant pathology and the breeding of plants for new varieties.

DISCUSSION

ORIGIN OF ASPHALTS, OIL, NATURAL GAS AND BITUMINOUS COAL

Cellulose and other carbohydrates, together with sufficient alkaline materials such as limestone, magnesite, dolomite, zeolite, etc., yield at higher temperature (230° C. and more) in the presence of water a plastic material—"proto product"—containing aliphatic, naphthenic and aromatic substances. Nitrogen and sulfur can be introduced easily into the proto product. This proto product gives on incomplete

hydrogenation or incomplete cracking an asphalt-like material. As natural asphalt or material like jet, the proto product gives on complete cracking or complete hydrogenation a mixture of aliphatic, hydroaromatic and aromatic hydrocarbons. This mixture is very much like natural oil. Asphalts and jets are therefore intermediate stages of the transformation of the proto product into oil and are not formed from hydrocarbons through the reaction with oxygen.

Humic acids formed from carbohydrates yield also on coalification proto products. Identical results can be obtained by coalification of saccharinic and lactic acids, which, in turn, can be formed from carbohydrates through alkaline treatment.

Lignin, on the other hand, and its derivatives, the so-called lignin-humic acids, do not yield by any treatment whatever material which on hydrogenation is changed into asphalt-like material or into a mixture resembling natural oil.

Fats and waxes do not yield hydrocarbons under the above-mentioned conditions of coalification.

Carbohydrates form on coalification gases containing low hydrocarbons and much CO_2.

Bituminous coals, giving excellent hard coke, can be produced by the coalification of carbohydrates, such as cellulose, with weakly alkaline water. They can not be obtained through coalification of lignin and its derivatives.

Natural gas, asphalts, oils and bituminous coals may therefore be derived from the same substances or their derivatives—the carbohydrates formed by nature on such a great scale.

The so-called animal theory, which explains the formation of oil by the heat decomposition of fish, and the lignin theory, which assumes that bituminous coals are derivatives of lignin, can not be substantiated by experiments.

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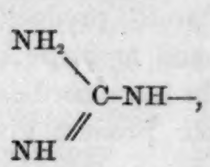
APRIL 23, 1934

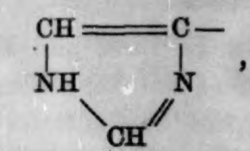
THE IONIZATION OF ARGININE AND HISTIDINE

CERTAIN anomalies in the behavior of the amino-acids arginine and histidine can be explained by the resonance theory.

The anomalies are as follows: The guanidine group of arginine is powerfully basic. The group does not react in the formaldehyde titration for the determination of amino groups. Yet its formula is usually written as

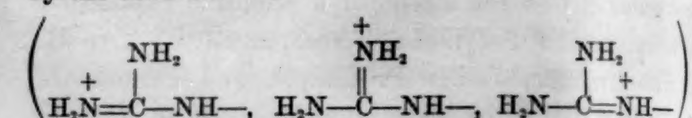


showing the presence of no powerfully basic radicals and revealing an amino group which should react in the formaldehyde titration. The imidazole group of histidine is definitely basic (pK′ = 6.0). Its formula is written



showing no detectable basicity.

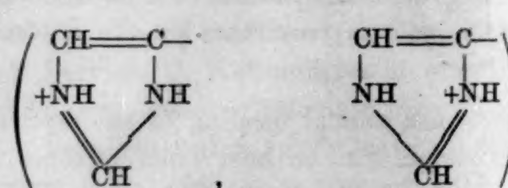
These anomalies may be explained by the assumption that the guanidine group adds H^+ not to the amino- but to the imino-group. The resulting ion has strong molecular resonance, and may be represented by the formula



This ion lacks the $-\overset{+}{N}H_3$ group which is necessary to the formaldehyde reaction

$$-\overset{+}{N}H_3 + HCHO \rightarrow -N{=}CH_2 + H^+ + H_2O$$

The imidazole group may be assumed to add hydrogen ion to form



the resonant condition of which accounts for the definite basicity of the group.

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CAUSE OF MORTALITY OF YOUNG GROUSE

FIELD studies in Algonquin Park, Ontario, during the present summer have shown the disappearance of young grouse (*Bonasa umbellus togata*) to be associated with a very high occurrence of a Leukocytozoon, of which the species has not yet been determined. Grouse in this area appear to be decreasing in numbers after having reached a peak of abundance last year. A mortality of at least 60 per cent. among chicks had taken place to mid-July in the area under immediate observation, and in practically all specimens examined, adult and young, the Leukocytozoon was found to be present. In view of the fact that similar parasites are known to be lethal to ducks and turkeys, a connection between its occurrence in grouse

and the high mortality observed is suspected. Field studies are still in progress.

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THE ROUTE OF INFESTATION AND THE SITE OF LOCALIZATION OF LUNG-WORMS IN MOLLUSKS

The proper study of the pathogenesis of the lesions in the lungs of vertebrates infested with lungworms is only possible, if we know the infestive stages of these parasites. From an economic point of view these stages have to be known to enable us to provide means for their control. Previously we demonstrated that a large group of lungworms of ruminants develops in certain pulmonata.[1,2,3,4] In the present work we wish to point out the route of infestation and the final site of localization of the parasites in their intermediate hosts.

The first stage larvae of these nemas, when brought in contact with the proper snails or slugs, bury themselves in the furrows of the sole of these intermediate hosts. A few hours later they may be seen entering the epithelial lining of the sole, after which they disappear in the layers of the muscular connective tissue of the foot. The pores of the foot glands facilitate this invasion, which takes place throughout the field of the furrows of the sole. The longitudinal sulci, if present, are preferred places of entrance. About twenty-four hours later the larvae coil up and the beginning of the formation of a parasitic tubercle is visible. Serial sections in transverse, sagittal and horizontal directions disclose that the nodules are restricted to the muscular connective tissue, which lays between and just above the foot glands. No further migrations can be observed. In the course of a few weeks the enclosed larvae molt twice and grow considerably. These larvae represent the infestive stages. The propagation of the parasites depends upon the ingestion at this stage of the intermediate hosts by the definite host. First stage larvae swallowed by the mollusks perish. Larvae entering the pedal cavity gland are rarely found.

The observations demonstrate that the localization of lungworms infesting mollusks is quite different from that observed for tapeworms or trematodes under similar conditions. They disclose a new type of infestation of mollusks with parasites of vertebrates.

A. and M. Hobmaier

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A SPECIFIC CONTAMINATION FOR THE PRODUCTION OF PSEUDO-RADIOACTIVITY

Some years ago I was confronted by what seemed artificially produced radioactivity. After the impingement of high velocity electrons on a platinum plate in vacuum, this plate subsequently seemed to emit high velocity electrons. The rate at which this pseudo-emission took place decayed to half value in about five days. The two apparent elements of radioactivity were discharge against high voltage and exponential decay thereof.

The simple experiment warrants reporting only to save others from this false trail. There was formed on the platinum plate a hydrocarbon deposit about 20 molecules in thickness. The impinging electrons became entangled in the hydrocarbon deposit, and of course bound equal positive charges. The apparent releasing of high velocity electrons was only the manifestation of the release of the bound charges, entangled in the hydrocarbon deposit.

F. C. Brown

SCIENTIFIC APPARATUS AND LABORATORY METHODS

A SIMPLE AUTOMATIC PUMP

In some work with the heart-lung preparation, an automatic pump was necessary in order to circulate a varying flow of blood against a pressure of 100 to 200 mm of mercury, in a system closed to room air. The pump here described meets these requirements and is simple in design and can be constructed without special parts. With the materials listed below, it can be assembled in 45 minutes.

1—6″ length of 1″ glass tubing.
3—Rubber stoppers, No. 7.
1—Small bottle, diameter of mouth 1″.
1—Toy balloon, ¾″ × 3″.
5—3″ lengths of 3 mm glass tubing.
Dental Rubber Dam.

The pump follows conventional design except for the substitution by a rubber balloon for the usual

1 A. and M. Hobmaier, "Ueber die Entwicklung des Lungenwurmes Synthetocaulus capillaris in Nackt- Weg- und Schnirkelschnecken," *Muenchener tieraerztl. Wochenschrift*, 80: 36, 1929.

2 A. and M. Hobmaier, "Limax und Succinea, zwei neue Zwischenwirte von Muellerius (Synthetocaulus) capillaris des Schafes und der Ziege," *Muenchener tieraerztl. Wochenschrift*, 80: 23, 1930.

3 A. and M. Hobmaier, "Life History of Protostrongylus (Synthetocaulus) rufescens," *Proc. Soc. Exper. Biol. and Med.*, 28: pp. 156–158, 1930.

4 A. and M. Hobmaier, "Elasphostrongylus odocoilei n. sp., a new lungworm in Black Tail deer (Odocoileus columbianus). Description and life history." *Proc. Soc. Exper. Biol. and Med.*, 31: pp. 509–514, 1934.

piston and cylinder, and the method of interrupting the outflow of air, which causes the blood to be forced out of the balloon.

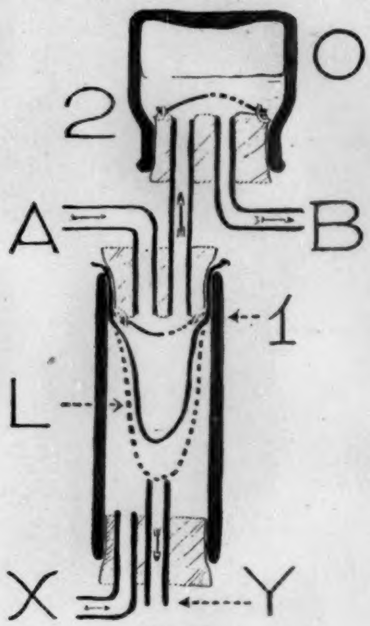

FIG. 1.

Compressed air flows from the main into the apparatus at X at a constant rate. Blood enters at A, flowing past the flap valve (1) and distending the balloon (L) forcing it down against the opening in the air exhaust tube (Y) and closing it off. A sudden increase in air pressure results and the tip of the balloon is held firmly against the opening in the exhaust tube. Then the blood inside the balloon is forced out past a second flap valve (2) into the bottle (0) which serves as an air cushion. As the hydrostatic pressure in the balloon (L) is decreased, the tip of the balloon is finally pulled away from the exhaust tube (Y) by the elasticity of the rubber wall of the balloon. Consequently, the air pressure in the apparatus is almost immediately released and air entering at the intake (X) again escapes from the exhaust (Y) at a constant rate. Within the range of its maximum capacity the speed of the pump is automatically adapted to the rate at which the blood is flowing in. When the inflow stops, the balloon does not fill and consequently the air exhaust (Y) remains open.

Flap valves, made of a portion of a toy balloon or, better yet, of dental rubber dam were found to be easily constructed and quite dependable. The rubber dam is sewed at its edges to the rubber stopper, being careful to allow enough slack so that blood flow is not impeded. As indicated in Fig. 1, the balloon (L) is slipped over the rubber stopper after the intake valve (1) has been completed.

Once the air exhaust tube (Y) is adjusted to the length of the balloon (L) and the optimum rate of air inflow determined, the pump works consistently with little attention. Our model pumps 600 cc per minute (about 10 cc per beat) against a hydrostatic pressure of 250 cm H_2O, with a pressure at the intake of about 20 cm H_2O.

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SPECIAL ARTICLES

TOXICITY OF NATURALLY OCCURRING ARSENIC IN FOODS

IT is well known that practically all marine life is naturally and inevitably richer in certain of the mineral elements than products from the land. The problem of the removal of arsenical spray residues from fruits and vegetables in order to make those foods safe for human consumption has recently focused the attention of investigators on the naturally high arsenic content of seafoods. Because of the increasing concern which is being shown by scientific workers at the present time the authors have undertaken to study the characteristics of the arsenic as it is contained in marine products when fed to laboratory animals.

Diets	Arsenic content of diets	Total ingested per rat		Total stored per rat		Per cent. of intake stored by rats	
		(Milligrams arsenic as As_2O_3)					
	Mgm As_2O_3 per kilo	3 mo.	5½ mo.	3 mo.	5½ mo.	3 mo.	5½ mo.
Stock diet[1]	0.20	0.24	0.46	—	0.07	—	14.3
Stock diet + As_2O_3	17.90	19.78	36.32	3.73	3.58	18.8	9.9
High arsenic shrimp[2]	17.70	19.23	36.26	0.13	0.26	0.7	0.7
Low arsenic shrimp[2] + As_2O_3	17.90	19.60	36.27	3.57	4.25	18.2	11.7
Low arsenic shrimp[2]	1.20	1.29	2.49	0.11	0.18	8.1	7.1

1 Sherman Diet 13 modified by Russell.
2 The meat scraps (10 per cent.) of the stock diet replaced by dried shrimp.

There is no direct experimental evidence available at the present time which proves that the natural arsenic in marine foods, if consumed regularly over long periods of time, will or will not produce harmful physiological effects. However, the fact that seafoods are eaten regularly by maritime peoples and have for centuries constituted the principal article of diet of some of the nations of the world without demonstrable harmful effects is presumptive evidence that the arsenic present therein is in a relatively non-toxic form.

In the investigative work reported here shrimps were chosen as the source of "naturally combined" arsenic, since it is known that arsenic occurs in shrimp in greater concentrations than in most other seafoods. Samples of shrimp have been encountered which range in arsenic content (as As_2O_3) from 171 to 5 milligrams per kilogram, dry basis.

Groups of rats were taken at weaning and fed diets of various arsenic content derived from shrimp and from added arsenic trioxide. At the end of 3 months and again at 5½ months of the feeding period representative animals from each group were killed, autopsied and sections of their liver, spleen and kidney examined histologically for evidences of injury due to arsenic feeding. The carcasses of the animals (without the alimentary canal) were also analyzed for arsenic.

It can be seen from the results shown in the accompanying table that although the carcasses of rats which had received the largest amount of arsenic, in the form of shrimp, contained about 4 times the quantity contained in the stock diet controls (with no added arsenic), the rats which had received approximately the same quantity of arsenic as arsenic trioxide contained from 55 to 65 times that in the control animals. The results also show that during the first 3 months of the feeding period as well as for the full 5½ months only 0.7 per cent. of the ingested "shrimp arsenic" was stored in the bodies of the rats, while more than 18 per cent. of the inorganic arsenic trioxide was stored in the first 3 months. Apparently the rats receiving the inorganic arsenic trioxide had, some time within the first 3 months of the feeding period, reached an equilibrium in which no more storage of arsenic was taking place. It is, therefore, impossible to calculate from the above results the percentage of arsenic which was stored before this equilibrium had been reached. Undoubtedly the percentage stored would have been much higher had the first feeding period been of shorter duration.

The above results are direct evidence that there is a difference in the metabolism of the arsenic as it occurs in shrimp as compared to inorganic arsenic and that only a very small percentage of the arsenic contained in shrimp is absorbed and stored in the animal body when such foods are eaten.

There was no retardation of growth in any of the arsenic-fed animals nor any observable differences in their physical vigor or appearance and in none of them was there any histological evidence of injury to the spleen, liver or kidney due to the feeding of arsenic at the levels here employed.

These experiments are being continued, with other rats scheduled to be killed at the end of 9 and 12 months.

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Roe E. Remington
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EXPERIMENTAL PRODUCTION OF INCREASED INTRACRANIAL PRESSURE

The production of a marked elevation in intraocular pressure by injecting small amounts of chloroform into the carotid artery of anesthetized dogs was described by Koppányi and Allen.[1]

We studied the effects of this procedure on the intracranial pressure. Dogs anesthetized with sodium barbital were used. Cisternal puncture was carried out and the needle connected with a water manometer. Blood pressure was recorded from one carotid artery, the other being used for chloroform injections. Injection of 0.2 to 0.5 cc of chloroform into the intact carotid artery produced a marked and sustained elevation of intracranial pressure. This elevation began in one or two minutes, reached a maximum in ten to twenty minutes, and remained approximately at the maximum level until the animal died. The usual level of the intracranial pressure before the chloroform injection was in the vicinity of 150 mm of water: the maximum height following chloroform injection was from 325 to 400 mm.

A coincident rise in intraocular pressure was produced by chloroform injections, corresponding to the observations made by Koppányi and Allen.

Once this elevated intracranial pressure was produced, the new high level seemed to be maintained much the same as the normal level. It varied directly with the level of arterial blood pressure. Alterations of arterial blood pressure resulting from the injection of epinephrine hydrochloride (marked rise), intravenous morphine sulfate (fall), intravenous 50 per cent. dextrose solution (initial fall and subsequent rise) and inhalation of amyl nitrite (marked fall) were invariably and immediately reflected by similar alterations in the increased intracranial pressure. Venous pres-

[1] *Proc. Soc. Exp. Biol. and Med.*, 12: 488, 1924–25.

sure (jugular) also followed the arterial blood pressure variations.

Similar experiments in which the intracranial pressure was not modified by chloroform injections showed no direct effect of morphine sulfate or of caffeine sodio-benzoate on the level of intracranial pressure, even when the drugs were given in large doses. When they were given intravenously, there was usually a temporary drop in blood pressure and a parallel drop in intracranial pressure. Hypertonic salt or dextrose solutions were the only agents which produced a rise in blood pressure without a corresponding change in intracranial pressure.

These studies are being continued.

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A STUDY OF THE COMPOSITION OF BLACK CONCRETIONS IN ONONDAGA LIMESTONE

IN the district about the Indian Ladder in the Thacher State Park, southwest of Albany, New York, are found many outcroppings of Onondaga limestone. In this region much blasting has been done to obtain rock for road construction. On the exposed face of one of these quarries was noticed many black spots surrounded by the usual gray of the limestone. In this gray limestone are to be found fossil sponges, corals, starfish, Brachiopods, mollusks and arthropods. Sponges were especially abundant during the Devonian Era. In conformity with this, many white calcite replacements have been recorded. On further examination, these black spots were found to be much more crystallized than the surrounding limestone, and seemed to be similar in shape but of varying dimensions. The shape was roughly ovoid and the dimensions varied from 2 to 8 inches long and 2 to 6 inches in diameter. About 100 pounds of this material were gathered for study. This material was then subdivided with a hammer and chisel to separate the limestone from the black crystalline material.

In nearly all cases these black nodules were found to be a hard central portion having a hardness above 6. This was found to be chert. After having separated the material into three parts, the usual limestone analysis was performed on each portion with the results shown in Table 1.

It is evident from these results that the black color of the black limestone is due to free carbon in a very fine state of subdivision. This carbon had excellent adsorbing properties. It was noticed that correct results could not be obtained for the carbon determination until the extracted carbon was heated for

TABLE 1

	Limestone	Chert	Black limestone
SiO_2	27.65	84.00	12.65
$Al_2O_3 + Fe_2O_3$	1.56	——	——
FeO	——	1.60	0.91
CaO	38.12	5.88	46.97
MgO	1.58	0.00	0.56
CO_2	31.00	6.35	37.85
Fe_2O_3	——	2.05	——
C	——	——	0.38
Na_2O	——		0.00
K_2O	——		0.00
TiO_2	——	0.00	0.00
P_2O_5	——	0.00	0.00
MnO	——	0.00	0.00
Al_2O_3	——		0.00
SrO	——		0.00
S	——		0.00
SO_3	——		0.00
N_2	——	0.00	0.00
Loss on ignition	31.70	6.33	38.60
Hardness	3	7	3
Color	Dark gray	Light gray	Black
Specific gravity	2.70	2.62	2.69

12 hours at 400° C. under reduced pressure. Unless this treatment was given, carbon dioxide obtained from the combustion of this material was unusually high. It was assumed that this excess was caused by adsorbed carbon dioxide. As phosphorus is generally found in fossils and neither phosphorus nor nitrogen were found in the stone, it indicates that they probably escaped as gases.

It is well known that sponges are very siliceous in texture, and upon decomposing leave a silica deposit. This explains the chert generally found at the center of these concretions. With decomposition there is a contraction in volume, thus leaving some space to be filled in. Water left by the decomposition had then dissolved the most soluble material, which was calcium carbonate. After a saturated solution was reached, the calcium carbonate precipitated as calcite. The crystalline form was rhombohedral. The dark color is probably due to the organic matter left by the sponge and was occluded as the calcite precipitated.

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